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PATENT SPECIFICATION

DRAWINGS ATTACHED

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Int. Cl.:—B 60 c 1/00

COMPLETE SPECIFICATION

Improved Pneumatic Tires

We, THE GOODYEAR TIRE & RUBBER COMPANY, a corporation organized under the laws of the State of Ohio, United States of America, of 1144 East Market Street, Akron, Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to pneumatic tires. More particularly, this invention relates to improved pneumatic tires embodying particular materials and a tire design having carefully controlled construction dimensions.

Conventionall pneumatic tires that are in use today are, for the most part, constructed with cotton, rayon or nylon cords. More recently polyester ~~fibres~~ fibers have been employed to produce high strength cords that have permitted tires to be built that have overall superior performance that results from improvements in treadwear, dimensional stability, and ride and handling characteristics. However, in spite of these superior properties of tires built with polyester cords, such tires have not in the past been completely successful, primarily because of the susceptibility of polyester cords to deteriorate rapidly at the very high temperatures that can be encountered in conventionally constructed tires during severe service.

It is an object of this invention to provide an improved pneumatic tire. Another object of this invention is to provide an improved pneumatic tire employing polyester cords in its construction. A further object of this invention is to provide a pneumatic tire that is not susceptible to excessive heat buildup during use and can therefore safely employ polyester cords in its construction.

The present invention consists broadly in a pneumatic tire having a carcass constructed with a multiplicity of plies made from polyester cords and a tread made from a ~~rubber~~ rubbery composition selected from (1) ethylene-propylene-terpolymer rubber and (2) a rubbery blend containing from 10 to 60 per cent by weight of cis-1,4 polybutadiene rubber, said tread having a tread shoulder gauge (as herein defined) constructed to be less than 850 mils.

In a preferred embodiment of the invention, wherein the tread is made from said ~~rubbers~~ rubbery blend containing 10 to 60% by weight of cis-1,4 polybutadiene rubber, the remaining 90 to 40% by weight of said rubber blend consists of at least one material selected from: a rubber copolymer of butadiene and styrene, natural rubber and cis-1,4 polyisoprene rubber.

Furthermore, in accordance with the present invention these tires are constructed in such a manner that they develop a minimum of heat buildup during use without sacrifice of other desirable properties, such heat buildup not exceeding 275°F. even when subjected to very rigorous conditions of use. In order to control the heat buildup in passenger tires constructed with polyester cords and the above-described tread composition, it has been found that the tire must be constructed with a "tread shoulder gauge" (TSG) that does not exceed 0.850 inch (850 mils). From a practical consideration, it is desirable to have as much rubber in the tread of a passenger tire as possible to give maximum treadwear providing other performance characteristics, such as heat buildup, are not seriously adversely affected. It has been found that a tread shoulder gauge of 0.600 inch (600 mils) will be a lower practical limit for most passenger tires when ethylene - propylene - terpolymer rubber or blends containing cis-1,4 polybutadiene rubber are employed in the tread. It has been found that the optimum tread shoulder gauge (TSG) for any given size passenger tire has the following

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relationship to the tire's "section width" (SW):

$$TSG = K\sqrt{SW}$$

where

TSG=tread shoulder gauge in inches
SW=section width in inches
K=a constant=0.28

The object of the present invention and the manner in which these objects are accomplished will be more readily understood by reference to the following description and accompanying drawings wherein:

Fig. 1 is a radial sectional view containing the axis of a tire.

Fig. 2 is a graph showing a plot of tire durability as a function of tire operating temperature for tires built in accordance with the invention and constructed with treads built from a blend of SBR and cis-1,4 polybutadiene rubbers and polyester cords;

Fig. 3 is a graph showing a plot of tire operating temperature and treadwear as a function of tread shoulder gauge. This graph is based on data obtained from tires constructed with (1) treads built from a blend of SBR and cis-1,4 polybutadiene rubbers and (2) polyester cord carcass plies.

Fig. 4 is a graph showing a plot of tire durability and treadwear rating as a function of tread shoulder gauge. The data on which this graph is based has been determined for tires built in accordance with the present invention employing polyester cord carcass plies and a tread compound from a blend of SBR and cis-1,4 polybutadiene rubbers.

Referring to Fig. 1, a pneumatic tire, generally indicated by the numeral "1" is comprised of a rubberized fabric body portion or carcass 2 of plies containing parallel cords having a tread 3 super-imposed and bonded to the crown area 4 of the carcass 2. Rubber sidewalls 5 and 6 extend from the respective edges of the tread over the carcass to bead portions 7 and 8. The dimension "A" from the outer surface 9 of the cords in the outer ply adjacent to the tread to the axially outer limit of the tread at the shoulder 10 is defined herein as "tread shoulder gauge". The dimension "B" from the underside of the carcass 2 radially outwardly to the top of the tread 3 is defined herein as "total centerline gauge". The dimension "C" from the outer surface 9 of the cords in the outer ply adjacent to the tread to the top of the tread 3 is defined herein as "tread center gauge". The dimension "D" from the outer surface 9 of the cords in the outer ply adjacent to the tread to the bottom of the groove in the tread 3 immediately adjacent the mid-circumferential plane is defined as "under tread gauge". Tread radius "E" is the radius of the arc formed by the tread surface measured in a plane containing the principal axis of rotation of the tire. The "section width" (SW) "F" is defined as the maximum axial width of the inside of the tire.

The term "passenger tire" as employed throughout this specification and the appended claims is defined as a tire of a size and type commonly used on motor vehicles designated as automobiles. Most passenger tires range in size from 6.00-13 to 9.50-14. A representative, but not all-inclusive, listing of USA passenger tire sizes is given in the 1962 yearbook of the Tire and Rim Association, pages 1-02 to 1-07.

Previous efforts to employ cords made from polyester fibers in the construction of tires have frequently resulted in cord failure when the tire was subjected to high speed service because heat buildup in the tire exceeded the point where polyester cords were stable. It has been found that if the operating temperature of the tire exceeds 275° F. polyester cords tend to deteriorate rapidly and the tire durability is sharply reduced at operating temperatures above 275° F. This relationship is shown in Fig. 2 wherein tire durability (in miles) is plotted as a function of tire operating temperature. The "tire durability test" is conducted according to the following procedure.

The tire to be tested is mounted on a standard heavy duty rim and inflated to a normal operating pressure, approximately 26 pounds per square inch for most passenger tires. The tire is then forced against a large cleated test wheel under a predetermined load that is approximately 120 per cent of the Tire and Rim Association's "maximum permissible load". The large driving wheel against which the tire under test is forced is equipped with six metal cleats 3/4 inch high and 2 inches wide evenly spaced around the circumference of the driving wheel and securely bolted thereto. The driving wheel and therefore the tire under test is rotated at 45 miles per hour and the results of the test are recorded as the number of miles the tire travels before tire failure occurs.

"Tire operating temperature" is measured by the use of a probe and thermocouple with the aid of a potentiometer. The probe is inserted into the tire at three predrilled holes in the shoulder area of the tire. The probe is first inserted into one of the test holes to warm it up and the temperature of the tire is then determined by making temperature measurements in the other two test holes.

It is a generally well known relationship that the greater the thickness of the tread rubber for any given rubber composition the greater will be the tread wear. However, there are practical limits which the tread thickness cannot exceed in most tire constructions. Since "heat buildup" is more pronounced in a tire with a thicker tread and since the shoulder area of a tread is the thickest portion of the tread the temperature buildup in the shoulder

area is the maximum encountered any place in the tire during its normal operation. The relationship between tire operating temperature and treadwear rating (determined as described hereinbefore) versus tread shoulder gauge for 8.20-15 passenger tires constructed in accordance with the present invention is shown by the values in the following table and by the plot of these values in Fig. 3.

Table 1

(Tread Shoulder Gauge) — Inches	Tire Operating Temp. °F.	Tread Wear Ratings
0.600	250	75
0.700	262	82
0.800	267	89
0.900	288	100

The treadwear rating of a tire is determined in accordance with the following procedure: The test is conducted on an automobile on an open highway that permits speeds of 70 miles per hour. Tires are tested at four pounds per square inch under the recommended Tire and Rim Association's inflation pressures and 7 per cent over the recommended Tire and Rim Association's loads. The tires are run continuously at 70 miles per hour until worn smooth and the number of miles covered is recorded and used as the basis for the rating of the tire against a standard tire that has been assigned an arbitrary treadwear rating of 100.

The treadwear rating may be defined as:

$$\frac{\text{number of miles necessary to wear the experimental tread to smoothness}}{\text{number of miles necessary to wear the control tread to smoothness}} \times 100$$

From the above discussion it will be apparent that "tread wear rating" increases with increased tread thickness, which for convenience can be measured on a comparative basis as the thickness of the tread at the shoulder, a dimension we have previously referred to as "tread shoulder gauge". It also follows from the preceding discussion that since "tire durability" decreases with increasing temperature and a tire operating temperature increases with increasing thickness of rubber in the tread which again can be conveniently measured at the shoulder as "tread shoulder gauge" that "tire durability" varies inversely with "tread shoulder gauge". The relationship between "tire durability" and "tread wear rating" as a function of "tread shoulder gauge" is shown by the values in the following table and by the plot of these values in Figure 4:

Table II

Tire Dimensions (Tread Shoulder Gauge) — Inches	Tire Durability Miles	Tread Wear Rating
0.600	4720	75
0.700	4160	82
0.800	4000	89
0.850	3130	95
0.900	995	100

The relationship between tire operating temperature and treadwear rating versus tread shoulder gauge was further evaluated with tires built in accordance with the present invention employing polyester cords in the carcass and treads made from EPT rubber. The carcass of these tires was built with two plies of 1100/3 polyester cord having 28 ends per inch.

Table III

(Tread Shoulder Gauge) — Inches	Tire Operating Temperature °F.	Tread Wear Rating
0.665	259°	81
0.690	261°	83
0.715	262°	84

The pneumatic tires that are to be built in accordance with the present invention each have a tire carcass which may contain two or more plies of parallel cords made from polyester fibers. By the term "polyester cords" as employed in this specification and the accompanying claims is meant cords produced of fibers prepared from linear polyester resins, the fibers having the following characteristics: (a) intrinsic viscosity in 60/40 phenol/tetrachloroethane at 30° C. greater than 0.55, (b) yarn tenacity in excess of 5.5 grams per denier and (c) a melting point greater than 450° F.

The ethylene - propylene -terpolymer (EPT) rubbers that may be used in compounding treads for tires constructed in accordance with the present invention are terpolymers having a sulfur-curable double bond that may be conveniently built into the ethylene-propylene polymer by introducing a third monomer into the polymer. This third monomer must be a non-conjugated diene wherein the double bonds are preferably separated by more than two carbon atoms. Useful sulfur-curable (EPT) rubbers are described in greater detail in U.S. Patent 2,933,480.

Cis-1,4 polybutadiene rubbers that are useful in compounding treads in accordance with the present invention are prepared by polymerizing butadiene in the presence of a catalyst formed by the interaction of organometallic compounds, such as trialkyl aluminum compounds, and a transition metal compound such as the titanium tetrahalides. Preferred trialkyl aluminum compounds are those in which the alkyl group contains not more than six carbon atoms. The polymerization reaction is usually conducted with the catalyst as the dispersed phase in a solvent monomer mixture. Catalyst base on TiI_4 are particularly effective in polymerizing butadiene to produce a polymer having a high percentage (90 per cent or more) of its diene units polymerized through 1,4 addition and in cis configuration. A more detailed description of the preparation of cis-1,4 polybutadiene rubbers may be found in the following references.

1. "New Controlled-Structure Polymer of Butadiene" Rubber and Plastic Age, March 1961, pp. 276—282 by W. W. Crouch
2. "1,4-Cis Polybutadiene" Gummi und Asbest, Vol. 13, p. 1026 (1960)

Cis-1,4 polyisoprene rubbers that are useful in compounding treads according to the invention are prepared by polymerizing isoprene employing the same general conditions and class of catalyst described above in connection with the polymerization of butadiene. Catalysts based on $TiCl_4$ and $TiBr_4$ are particularly effective in polymerizing isoprene to produce a polymer having a high percentage (90 per cent or more) of its diene units polymerized through 1,4 addition and in cis configuration. A more detailed description of the preparation of cis-1,4 polyisoprene rubbers may be found in the following references.

1. "Synthetic Natural Rubbers from Isoprene" Rubber and Plastic Age, Vol. 39 No. 11 Page 938 (1958) by Mayor, Saltman and Pierson
2. "Cis-1,4 Polyisoprene Prepared with Alkyl Aluminum and Titanium Tetrachloride" Industrial and Engineering Chemistry, Vol. 50 Pages 1507—1510 (1958) by Adams, Stearns, Smith and Binder.

The rubbery copolymers of butadiene and styrene that are useful in compounding treads in accordance with this invention are copolymers containing from 50 to 90 per cent butadiene.

When cis-1,4 polybutadiene is blended with other rubbers such as natural, SBR or cis-1,4 polyisoprene to produce treads that are to be employed in building tires of the present invention, the cis-1,4 polybutadiene rubber may make up from 10 to 60 per cent of the rubber in the tread compound and the other rubber will constitute from 90 to 40 per cent of the rubber in the tread.

A consideration of the data that has been shown above will make it apparent that in a tire constructed with polyester cords and with either EPT rubber or a rubber blend containing a substantial percentage of cis-1,4 polybutadiene rubber in the tread that "tread shoulder gauge" is a dimension that must be controlled within rather critical limits. It has been found that if the "tread shoulder gauge" exceeds approximately 850 mils then the tire durability decreases rapidly, primarily because of excessive heat buildup. This relationship is shown in the plots presented as Figs. 3 and 4.

In addition to controlling the "tread shoulder gauge" of passenger tires built in accordance with the present invention so that it will not exceed 850 mils, it may in some instances be found desirable to control the TSG so as to be at least 600 mils.

It may also frequently be desirable to control other specific dimensions of the tire produced in accordance with the present invention within definite limits. These other dimensions that may be desirable to control are:

1. "Total centerline gauge" between 600—780 mils.
2. "Tread center gauge" between 400—490 mils.
3. "Under tread gauge" between 75 and 110 mils.
4. "Tread radius" between 7.0 and 11.0 inches.

However, the tire dimensions other than the "tread shoulder gauge" do not necessarily need to be controlled in tires built in accordance with the present invention.

A typical 8.00-14 tire in accordance with the present invention was built on a tire carcass constructed with four plies of 1100/3

cords made of polyethylene terephthalate and having 25 ends per inch. The tread was compounded from 20 per cent of cis-1,4 polybutadiene rubber and 80 per cent SBR. The "tread shoulder gauge" was 790 mils; the "total centerline gauge" was 700 mils; the "tread center gauge" was 470 mils, the "under tread gauge" was 90 mils and the tread radius was 10 inches.

Construction of a typical tire in accordance with the present invention has been demonstrated in the foregoing example employing polyethylene terephthalate cords in the carcass. In addition to polyethylene terephthalate other linear polyesters and particularly linear polyesters of aromatic dicarboxylic acids may be employed in building tires in accordance with the invention. Representative examples of such polyesters are polycyclohexane dimethyl terephthalate, polytetramethylene terephthalate and high melting copolyesters, such as 90/10 ethylene terephthalate-ethylene isophthalate copolyester. It should be understood that any of these linear polyesters must have fibers whose intrinsice viscosity, yarn tenacity and melting point are within the limits discussed above.

WHAT WE CLAIM IS:—

1. A pneumatic tire having a carcass constructed with a multiplicity of plies made from polyester cords and a tread made from a rubber composition selected from (1) ethylene-propylene-terpolymer rubber and (2) a rubbery blend containing from 10 to 60 per cent by weight of cis-1,4 polybutadiene rubber, said tread having a tread shoulder gauge (as herein defined) constructed to be less than 850 mils.

2. A pneumatic tire according to Claim 1, said tread being further characterized by being constructed to have a tread shoulder gauge with the following relationship to the tread section width (as herein desfined);

$$TSG = K\sqrt{SW}$$

where

TSG = tread shoulder gauge in inches

SE = section width in inches

K = a constant = 0.28.

3. A pneumatic tire according to Claim 1, the tread being made from said rubbery blend containing 10 to 60 per cent by weight of cis-1,4 polybutadiene rubber, wherein the remaining 90 to 40% by weight of said rubbery blend consists of at least one material selected from a rubbery copolymer of butadiene and styrene, natural rubber, and cis-1,4 polyisoprene rubber.

4. A pneumatic tire according to Claim 3, having the following initial dimensions:

(a) "tread shoulder gauge" (as herein defined) between 600 and 850 mils;
(b) "total centerline gauge (as herein defined) between 600 and 780 mils;
(c) "tread center gauge" (as herein defined) between 400 and 490 mils;
(d) "undertread gauge" (as herein defined) between 75 and 100 mils;
(e) "tread radius" (as herein defined) between 7.0 and 11.0 inches.

5. A pneumatic tire according to Claim 4, having substantially the following initial dimensions:—

(a) "tread shoulder gauge" (as herein defined) 780 mils;
(b) "total centerline gauge" (as herein defined) 750 mils;
(c) "tread center gauge" (as herein defined) 470 mils;
(d) "undertread gauge" (as herein defined) 100 mils;
(e) "tread radius" (as herein defined) 10.0 inches.

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ERRATA

SPECIFICATION No. 1,081,980

Page 1, line 19, *for* "fibres" *read* "fibers"
Page 1, line 44, *for* "rubber" *read* "rubbery"
Page 1, line 52, *for* "rubbers" *read* "rubbery"

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16th October 1967

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(b) "total centerline gauge (as herein defined) between 600 and 780 mils;
(c) "tread center gauge" (as herein defined) between 400 and 490 mils;
(d) "undertread gauge" (as herein defined) between 75 and 100 mils;
(e) "tread radius" (as herein defined) between 7.0 and 11.0 inches.

5. A pneumatic tire according to Claim 4, having substantially the following initial dimensions:—

(a) "tread shoulder gauge" (as herein defined) 780 mils;
(b) "total centerline gauge" (as herein defined) 750 mils;
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